CHARACTERISTICS OF THE ORGANIC MATTER IN THE MAJOR SOILS OF THE WORLD AND ITS IMPORTANCE TO SOIL FERTILITY

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Organic matter is one of the most important factors in soil fertility. It is indispensable to plant life in its natural environment. This is why the result of the alteration of the lithosphere (crust of weathering) is not considered a soil by pedologists unless it is accompanied by a process involving living organisms.

Action of the organic matter

The action of the organic matter, or rather, of the humus which results from its decomposition and from new synthesis, can be either direct or indirect. The humus seems to act directly in increasing crop yields, either by acceleration of respiratory processes, by increasing cell permeability, by hormone growth action, or by combinations of all these processes. It supplies the plants, through biological decomposition, with nitrogen, sulphur and phosphorus in available form. Indirectly, it improves the physical properties of the soil such as aggregation, aeration, permeability and water-holding capacity.

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Relation of organic matter to soil fertility

Because of its complex role, it is difficult to evaluate the importance of organic matter to soil productivity. Most experiments, particularly field experiments, can only estimate roughly the part played by humus and that by the mineral elements in the humus. The macro and microelements supplied by manure can, of course, be replaced by fertilisers. In fact, in nature, organic matter does not supply the mineral plant nutrients. It concentrates and stores them in the surface of the soil. Its capacity to retain and exchange elements such as calcium, magnesium and potassium, prevents over-leaching of soils poor in clay. Given equal weights, the exchange capacity of organic matter is between two and twenty times that of the clay. Even if fertilisers alone could satisfy plant needs, organic matter would still be needed for erosion control and to reduce losses of such costly inputs through leaching. Perhaps one day there will be a synthetic resin capable of replacing organic matter in its exchange function at a price economically feasible.

Organic matter also is difficult to replace in its role in the improvement of the physical properties of the soil. Clay needs good aggregation because of the possibility of dispersion. Aggregation can be obtained by iron oxides, for instance, but then the exchange capacity is low, and although permeability is increased, water retention diminishes. Krilium and other similar compounds raised great hopes at one particular stage but the general application of such conditioners is still uneconomic.

Finally, its role as a catalyser of plant growth does not yet seem to be fully understood. However, chemistry is powerful and it is likely that chemicals will be found to replace organic matter in this particular property, since the amounts required are likely to be small.

If organic matter and humus are still indispensable to us, what should be the quality of the organic matter and in what proportions is it needed? It is difficult to answer the first question without answering the second since the relationship between organic matter content and yield often seems to depend both on the composition of the soil and the quality of the humus.

The significance of humus quality is a particularly complex question and much research is still needed to understand it fully. To date, it has been assessed by a few simple criteria such as physical aspect, pH, percentage base saturation, Humic acid/Fulvic acid ratio, carbon/nitrogen ratio, etc. Generally, the most effective humus has neutral pH, high base saturation, a H/F ratio larger than 1, and a C/N ratio around 10. It is important to understand for each crop the influence of the C/N ratio for equal applications of organic matter. A study of this kind was undertaken by YOSHIHISA MASHIMO [5] as shown in diagram 1. On the other hand, D.S. BULGEHEV [1] obtained the following relation between the content of organic matter/yield of a mixed fodder (vetch, oats, peas) for organic matter with nearly constant C/N ratio:

$y = 50.6\ x - 8.68$ in which x is the percentage or organic matter ranging between 0 and 3%.

Diagram 2 represents the ratio of organic matter content to the production of wheat and maize.

The kind of crop should be specified since they do not all respond in the same manner. Although the C/N ratio generally indicates the availability of nitrogen in the organic matter, each plant has its specific requirements of this plant nutrient. Trees in general and certain saprophites, such as vanilla, grow well with C/N ratios up to 35. Above this, nitrogen deficiencies may occur.

Most plants seem to respond very well to an increase from 0 to 7% of organic matter of suitable C/N ratio; after which

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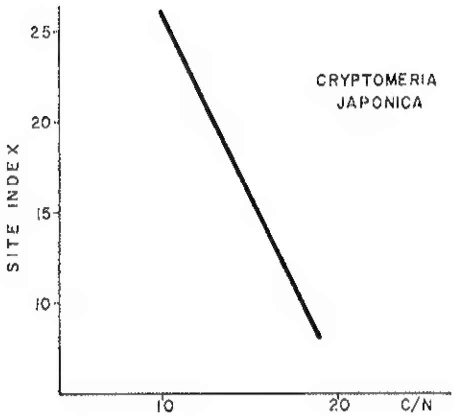
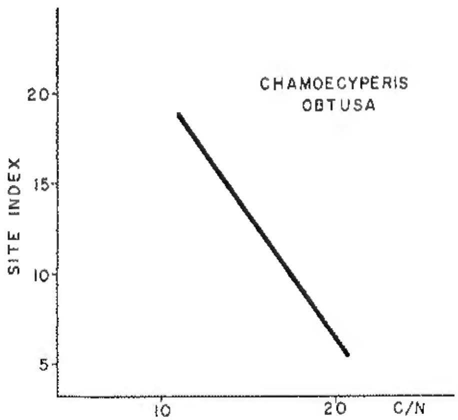
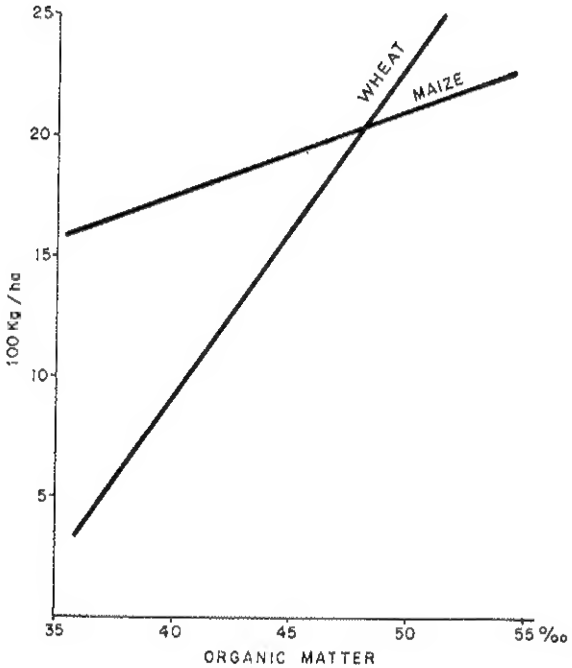




[2] *Bramao* - pag. 4

DIAGRAM 2



[2] *Bramao* - pag. 5

growth increases more slowly following a curve of the Mitcherlich type. J. VELLY and others describe changes in an exposed, compact B horizon of a Ferralsol from Madagascar, containing 1.35% carbon and 0.10% nitrogen. The control plot gave no yield of maize. With an application of 10 tons of bad quality manure, 231 kg/ha were obtained. With the addition of 200 kg of ammonium sulphate, 100 kg of urea, 300 kg of 18% superphosphate and 200 kg of 60% potassium chloride, the yield was increased to 2175 kg/ha. The manure alone and 300 kg of 18% superphosphate yielded only 269 kg/ha. Therefore, it seems that in this soil, manure alone was capable of supplying very little of the nitrogen requirements of the crop. It was the nitrogen fertiliser, plus the application of P and K, which significantly raised the productivity of this eroded soil.

The action of the organic matter on soil structure is difficult to measure as it varies with texture, kind of clay, etc. However, organic matter will reduce bulk density of the soil and improve its structure. There are, however, interactions with other factors. For example, DABIN [2] established that, with more than 2% of organic matter, a ratio Na/Ca 0.08 to 0.1 has a bad effect on soil structure. With less than 1% of organic matter a ratio Na/Ca from 0.03 to 0.05 is sufficient to have the same effect.

ORGANIC MATTER IN THE MAJOR SOILS OF THE WORLD

Each Great Soil Group under natural conditions has a characteristic range of quantity and quality of organic matter as a result of the natural equilibrium between accumulation of organic matter and its mineralisation. This equilibrium depends on the climate, organisms and parent material. It is upset by the interference of man with resultant modifications of the quality and content of organic matter.

[2] *Bramao* - pag. 6

TABLE

Major soils ([1])		Organic matter content ([2])	$\frac{C}{N}$ ([2])	pH ([2])	Base saturation ([2])
Fluvisols		low	variable	variable	variable
Rhegosols		low	variable	variable	variable
Arenosols		low	medium	acid	low
Gleysols	ochric	low	medium to high	acid	variable
	humic	medium to high	medium to low	neutral	variable
	histic	very high	high	low	variable
Rendzinas		medium to high	medium	neutral to basic	high
Rankers		medium	medium	acid	low
Andosols		variable	medium to high	acid to neutral	—
Vertisols		low	medium	neutral	high
Ermosols		low	low	basic	high
Xerosols		low	low	basic	high
Halosols	ochric	low	medium	basic	high
	humic	medium to high	medium	basic	high
	solod	medium	medium	neutral to acid	medium
Planosols	ochric	low	medium	acid	low to medium
	humic	medium to high	medium	neutral	medium to high
Castanozems		medium	medium	neutral	high
Chernozems		medium to high	medium	neutral	medium to high
Phaeozems		medium to high	medium	slightly acid	medium
Cambisols	ochric	low	medium	slightly acid	low
	humic	medium	medium	acid	low
Luvisols		medium	medium	slightly acid to neutral	medium to high
Acrisols		low to medium	medium	acid	low
	humic	high	high	acid	low
Podzols		variable	high	acid	low
Ferralsols		low to medium	medium	acid	low to medium
	humic	high	high	acid	
Histosols		very high	high	variable	variable

([1]) Nomenclature and definitions internationally agreed and used in the preparation of the FAO/UNESCO Soil Map of the World (see WSRO note page 49).

This table refers only in a very approximate way to the average organic matter content in the major soils and related properties and conditions. It presupposes that the soils mentioned are uncultivated or under the so-called traditional agriculture.

Soils of regions where technological agriculture predominates may belong to the groups indicated, but may have also quite different qualities and properties of their organic matter due to soil management.

Whenever organic matter content in the soil and percentage of base saturation are medium to high soils are naturally fertile and productive. Agriculture can be established on this soil areas without much investment, provided, of course, that no other particular limiting factors are involved, such as presence of salinity or water-logging conditions. However, such limitations and others, such as shallowness or very coarse textures, are considered to be of local character when one looks at the extention of the soils on a global basis.

From the information which led to the preparation of the table, it can be estimated that while, under natural conditions, about 60% of the soil units of the world soil legend are well

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Report No 33 - Definitions of the Soil Units for the Soil Map of the World).

(²)

Organic matter content:	below 2%	low
	2 to 6%	medium
	7 to 30%	high
	above 30%	very high
C/N ratio:	below 10	low
	10 to 14	medium
	15 to 30	high
	above 30	very high
pH:	below 5.2	acid
	5.3 to 7.5	slightly acid to neutral
	above 7.5	basic
Base saturation:	below 35%	low
	36 to 60%	medium
	above 60%	high

supplied with organic matter, the remainder are low or very low in organic matter.

Organic matter content is here referred to in terms of soil classification and not in terms of soil areas. It would have been desirable to present information on the organic matter content of the major soil areas, but the measurements and computation involved, being undertaken in FAO for the evaluation of world soil resources for agricultural production, are not yet sufficiently complete.

The table shows, always in approximate terms, the percentage of base saturation of the surface horizon of the major soils where organic matter is mostly concentrated. This is considered to be a very important criteria in relation to soil fertility and production. This is particularly important when considering the potentiality of project areas in the developing countries. In fact, soils with low saturation are often « problem soils » in agricultural development. Soils with high saturation are, in the absence of limiting factors, such as salinity and shallowness, usually the best soils of the tropical and subtropical regions.

DISCUSSION

Chairman: S. A. WAKSMAN

HERNANDO

I understood in your statement that you foretold that the organic matter does not produce good results when it is applied to the soil if the sodium and calcium ratio in the exchange capacity is high. Is this exact?

BRAMAO

What I meant was that for a high organic matter content a wide sodium calcium ratio is less harmful on the structure of the soil than for a low organic matter content.

HERNANDO

Because I heard also in relation with that last month in Arizona they got some problems when they tried to apply organic matter to soil citrus growing. They observe some deficiencies in the trees when they apply organic matter, and that is in some respect similar to what you were saying.

BRAMAO

I did not hear your question very well. When you say that in the case of citrus...

HERNANDO

In Arizona in the United States, in one experimental station in Tempe, they told me that they have some problems when they apply organic matter to the soil. Still the soil is not high in organic matter; it develops deficiencies in the trees, but this looks very surprising. Is it something similar to what you told us in your paper, and also I ask you if you have some explanatory information for that?

BRAMAO

I think that of course to answer your question one needs to know the kind of soils, the presence or absence of salinity, and also the kind of organic matter applied.

HERNANDO

Well, the soils also are in this case high in calcium and in your paper the soil is high in sodium, is it not? In this case it is the contrary. But the result is the same. Maybe there is not a clear explanation for that, but I am interested to know if you or somebody else here can give some ideas about the possibilities of explaining this result.

BRAMAO

It seems that in soils high in calcium, citrus trees frequently develop iron deficiencies.

[2] *Bramao* - pag. 12

HERNANDO

Yes, they get the iron deficiencies but when organic matter is applied, not before. If no organic matter is applied, there should not be iron deficiency. Is that not surprising?

WAKSMAN

I would like to ask Prof. BRAMAO what he meant by bad manure.

BRAMAO

This is a very bad expression. I do realize it. I did not like to put it but that is how it was in the Author's paper.

SWABY

Prof. BRAMAO, I noticed that your aim is ultimately, I presume, to produce a world map showing the distribution of organic matter in the major soils of the world. The Russians have been doing this sort of work also. Whether there is any integration between your team and the Russians, I don't know, but some of this work is going to be discussed at Adelaide and I have had a preview of some of their papers and I would think that for a continent like my own, Australia, they must have done some very wild guessing as to contents of organic matter because we ourselves do not even know. That is because no really good analysis has been done, and I imagine that in your own classification you must have had some guessing to do also. How do you make these assessments? I would like to know something about the techniques you use.

BRAMAO

First I would like to answer your first question. We are not preparing the USSR part of the soil map of the world. Prof. KOVDA, who is not here today but was supposed to be, Academician Gerasimov and Prof. LOBOVA, make part of the Advisory Panel for the Soil Map of the World and are responsible for the Soviet contribution. There is an integration at the level of establishment of the common legend and agreement on the definition of soil units. This was difficult. It was, in 1966, in Moscow, during the 5th Advisory Panel meeting of the Soil Map of the World that an agreement was reached. Dr. HALLSWORTH and his group at Adelaide are preparing a 1/5,000,000 soil map of Australia integrated in the soil map of the world, using the international legend. The World Soil Resources Office of FAO, in cooperation with specialists from the countries concerned, is preparing the Soil Maps of South and Central America, Europe and Africa. The North America map (Canada, the United States and Mexico) is being put together in the U.S. Soil Conservation Service. The Canadian part was done under Dr. LEHEAY and ELRICH. After the completion of the map it will be possible to see the distribution of a soil on a world wide basis. The first thing one learns is that a soil can occur in different climates, as far as crop production is concerned. So we found that the Vertisols occur in several continents under some eigbt or nine major crop climatic conditions.

NORMAN

I think that perhaps in your last remark you went far in answering the question I was going to ask. It has always troubled me when we talk about making a Soil Map of the World, what we are really mapping. Are we trying to map the undeveloped soils of the world or are we trying to map soils of the world as we think they were before they were subjected to intensive agriculture? I

realize that in some parts of the world there is no distinction between these two groups but when I think of the soils of Britain, for example, that have been cultivated for many hundreds of years, or the soils of Pennsylvania that surely are very different now from what they were as virgin soils, I wonder what we really are mapping.

BRAMAO

I think we are trying to show the soils as they are rather than as they were. I think that in large areas of the world, soils are not very much disturbed. But in other parts, in the highly developed areas, of course they have changed much with agriculture.